Name ____ AP Chemistry

Exploring Buffers and Buffer Capacity

Introduction

Acids and bases represent two of the common classes of compounds. An important reaction of Bronsted-Lowry acids and bases is one in which an acid and base are combined, resulting in the formation of a salt and water. This reaction is called a neutralization reaction. In the last experiment, you learned to what extent the strength of an acid or base related to its ionization in an aqueous solution.

A buffer solution is one that contains both a weak acid (HA) and its conjugate base (A^-), usually as a sodium or potassium salt, in sufficient concentrations so as to maintain a relatively constant pH when either strong acid or base is added. A buffer resists pH change by the weak acid component reacting with any externally added based and similarly, the weak base component reacting with any externally added acid.

The Henderson-Hasselbalch equation is used to describe solutions that have both a weak acid in solution with its conjugate:

$$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$$

The Henderson-Hasselbalch equation is just a logarithmic form of the K_a expression. It also illustrates that when $[HA] \approx [A^-]$, the solution's pH will be close to the pK_a of the acid. Buffering capacity describes the working range of the buffer. When too much strong acid or base is added, we say the buffer capacity has been exceeded because substantial changes in pH are observed. The buffering capacity is calculated using the following expression:

$$buffer\ capacity = \frac{\Delta n}{\Delta pH}$$

where Δn is the number of moles of strong base or strong acid added to the buffer. In this virtual experiment, you are going to first create a buffer and then explore the buffering capacity by adding an strong acid and then a strong base.

Procedure

1) Go to the class website. Click on "Unit VII-Acid-Base Chemistry & Aqueous Equilibrium" on the left sidebar. Scroll to the bottom of webpage and click on the link for "Exploring Buffers and Buffer Capacity."
2) Select '$HC_2H_3O_2$' under Acid/Base and '$NaC_2H_3O_2$' under Salt. Set the molarity to 50 x 10^{-2} for both solution. Keep the volume at 100.00 mL each.

3) Click ‘Insert Probe’ and record the pH in the Data Table I under 0 mol. Click ‘Remove Probe’ and then choose ‘Go to Part II.’
4) Make sure ‘Acid’ is chosen under Test Solutions. Choose a strong acid from the list of acids and note which acid you choose in Data Table I
5) Set the number of moles to ‘5.00×10^{-3}’ mole. Measure the pH of the solution and record it in the Data Table I under 5.00×10^{-3} mol of acid.
6) Change the moles to 10.00×10^{-3}. Measure and record the pH. Continue changing the number of moles by 5.00 moles and recording the pH until you have added 50×10^{-3} mol.
7) Now choose ‘Base’ under Test Solutions and pick a strong base from the list of bases and note which acid you choose in Data Table I.
8) Set the number of moles to ‘5.00×10^{-3}’ mole. Measure the pH of the solution and record it in the Data Table I under 5.00×10^{-3} mol of base.
9) Change the moles to 10.00×10^{-3}. Measure and record the pH. Continue changing the number of moles by 5.00 moles and recording the pH until you have added 50×10^{-3} mol.
10) Click on ‘Go to Part I.’ Now chose ‘NH_3’ under Acid/Base and ‘NH_4Cl’ under Salt. Set the molarity to 50×10^{-2} for both solution. Keep the volume at 100.00 mL each.
11) Repeat steps 3-9, recording all pHs in Data Table II.
12) Graph the moles of acid (x-axis) versus pH (y-axis) and then graph the moles of base versus pH for acetic acid-acetate buffer in one graph. Make sure to note which line is for acid and which is for base.
13) Repeat step 12 for the ammonia-ammonium buffer.

Results

Data Table I

Strong Acid:		***Strong Base:***	
Moles of Acid Added	**pH**	**Moles of Base Added**	**pH**
0		0	
5.0×10^{-3}		5.0×10^{-3}	
10.0×10^{-3}		10.0×10^{-3}	
15.0×10^{-3}		15.0×10^{-3}	
20.0×10^{-3}		20.0×10^{-3}	
25.0×10^{-3}		25.0×10^{-3}	
30.0×10^{-3}		30.0×10^{-3}	
35.0×10^{-3}		35.0×10^{-3}	
40.0×10^{-3}		40.0×10^{-3}	
45.0×10^{-3}		45.0×10^{-3}	
50.0×10^{-3}		50.0×10^{-3}	

Data Table II

Strong Acid:		***Strong Base:***	
Moles of Acid Added	**pH**	**Moles of Base Added**	**pH**
0		0	
5.0×10^{-3}		5.0×10^{-3}	
10.0×10^{-3}		10.0×10^{-3}	
15.0×10^{-3}		15.0×10^{-3}	
20.0×10^{-3}		20.0×10^{-3}	
25.0×10^{-3}		25.0×10^{-3}	
30.0×10^{-3}		30.0×10^{-3}	
35.0×10^{-3}		35.0×10^{-3}	
40.0×10^{-3}		40.0×10^{-3}	
45.0×10^{-3}		45.0×10^{-3}	
50.0×10^{-3}		50.0×10^{-3}	

Graphs

Questions

1) For the acetic acid-acetate buffer, write the equation for the reaction of the buffer with the strong acid and then write the equation for the reaction of the buffer with the strong base.
2) For the ammonia-ammonium buffer, write the equation for the reaction of the buffer with the strong acid and then write the equation for the reaction of the buffer with the strong base.
3) (a) Calculate the buffer capacity for the acetic acid-acetate buffer reacting with the strong acid by determining the slope of the line. Then calculate the buffer capacity for the acetic acid-acetate buffer reacting with the strong base.
   (b) Give the buffer capacity range using your answer for part a.
4) (a) Calculate the buffer capacity for the acetic acid-acetate buffer reacting with the strong acid by determining the slope of the line. Then calculate the buffer capacity for the acetic acid-acetate buffer reacting with the strong base.
   (b) Give the buffer capacity range using your answer for part a.
5) Compare and contrast the buffer capacity of the acetic acid-acetate and ammonia-ammonium buffers. Which has the best buffer capacity ability?
6) Give two examples of the use of buffers in the everyday world (i.e. use google).